Libera Science Beyond L-1b

LASP • JPL • LBL • UA • CSU • UM • NIST • NOAA • Ball • SDL

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Mother and Daughter

Libera Overarching Science Goals

Meet EVC-1 specific objectives on Earth Radiation Budget (ERB) continuity, innovation, and affordability.

OG1: Provide seamless continuity of CERES ERB Climate data record (CDR).

- Measurement of TOT, SW and LW with same characteristics as CERES.

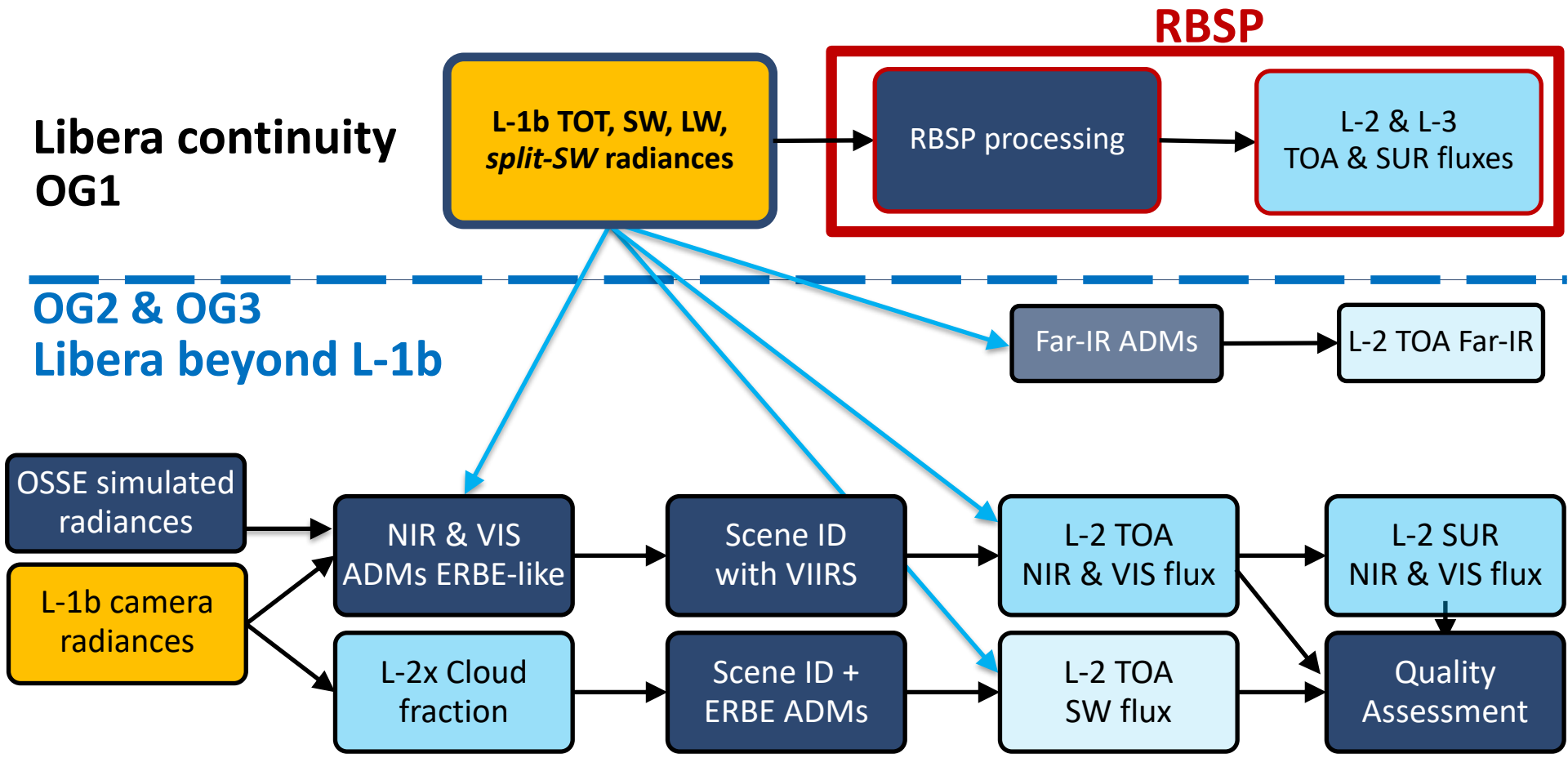
OG2: Advance the development of a self-contained, innovative & affordable observing system.

- Miniaturized radiometers
- Wide field-of-view camera for Scene ID and split-SW ADM development.

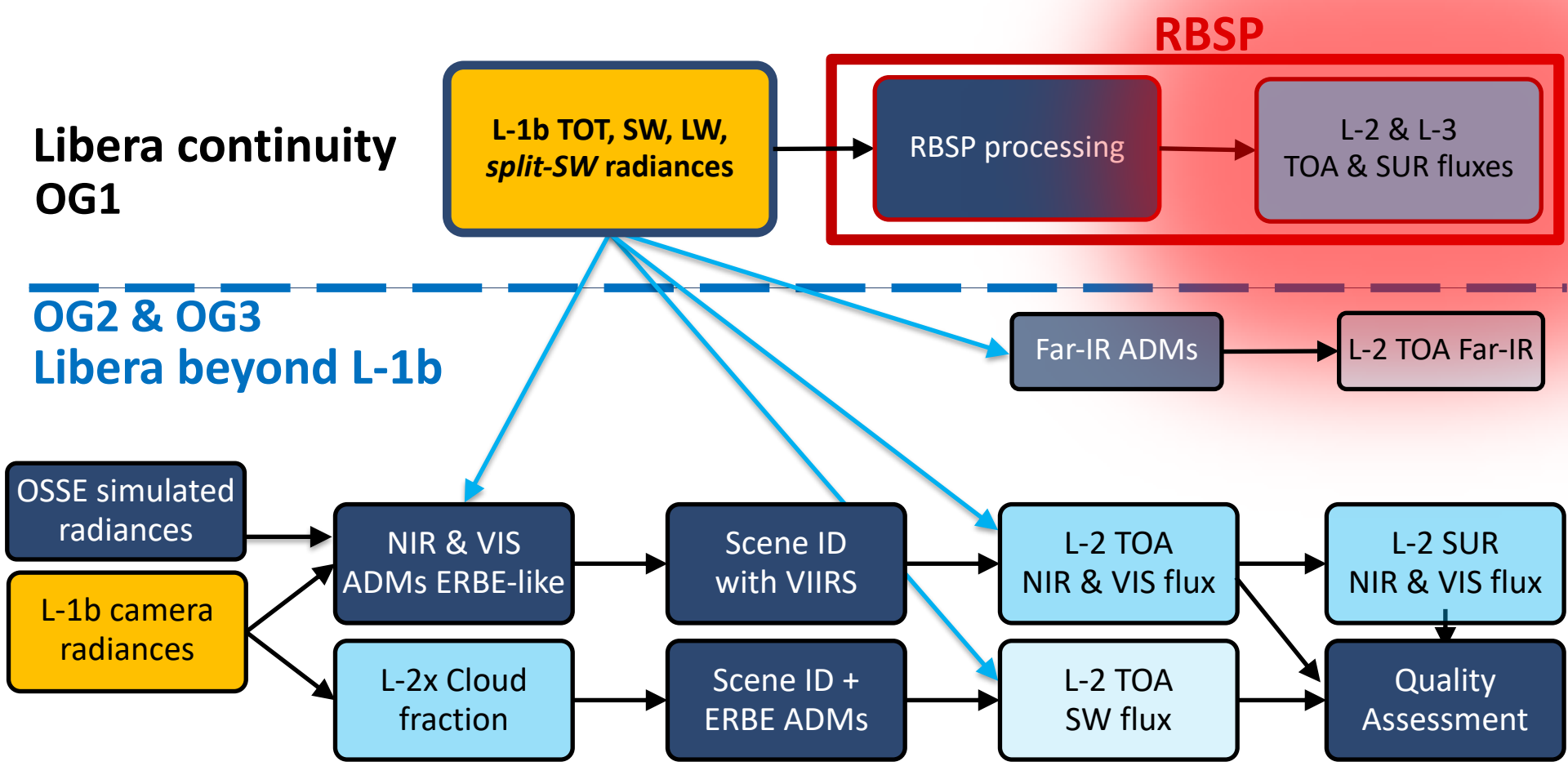
OG3: Provide new and enhanced capabilities that support extending ERB science goals.

- Additional split-SW channel to quantify shortwave near-IR and visible flux.

Libera Science & Data Plan



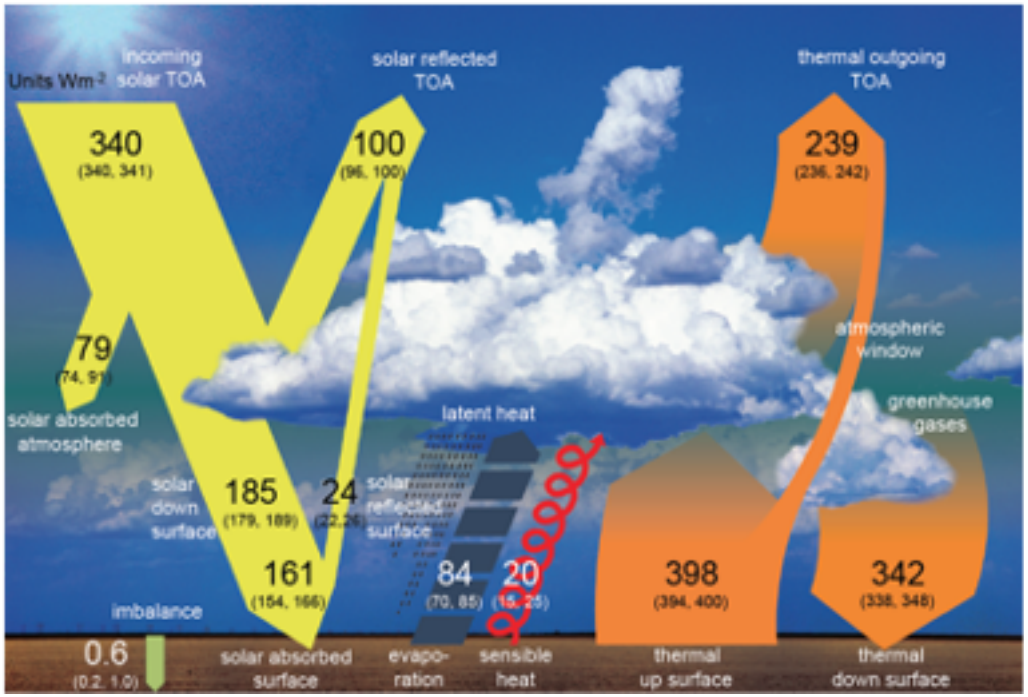
Libera Science & Data Plan



Libera Science Objective 1

OG1: Provide seamless continuity of the ERB Climate data record.

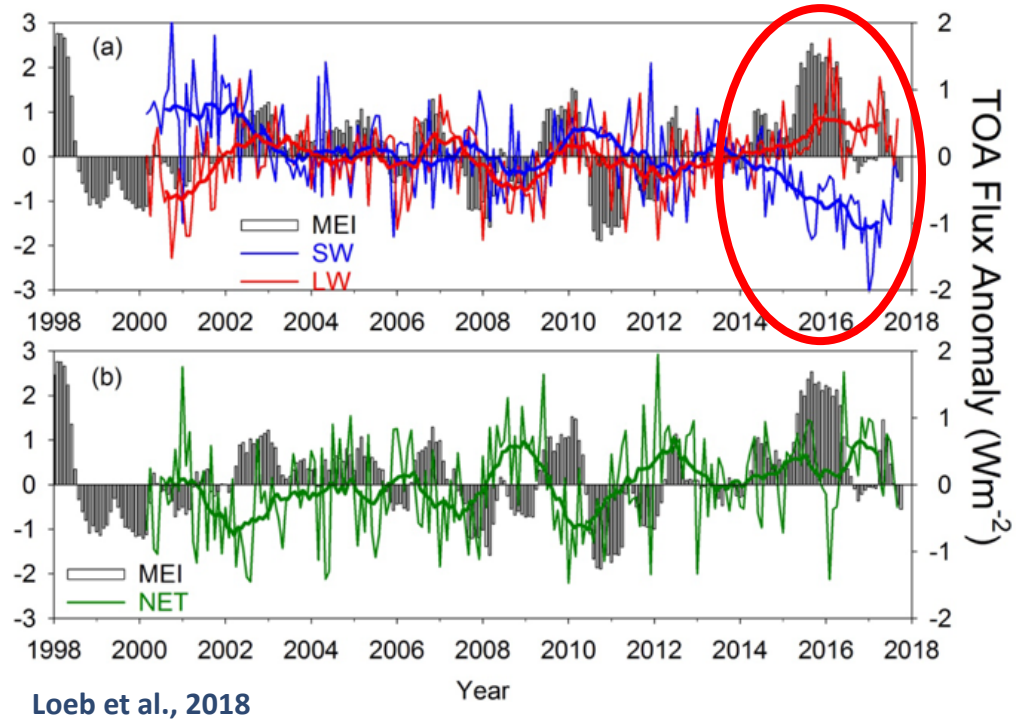
Science objective 1: Use extended CDR to identify and quantify processes responsible for ERB variability on various times scales.



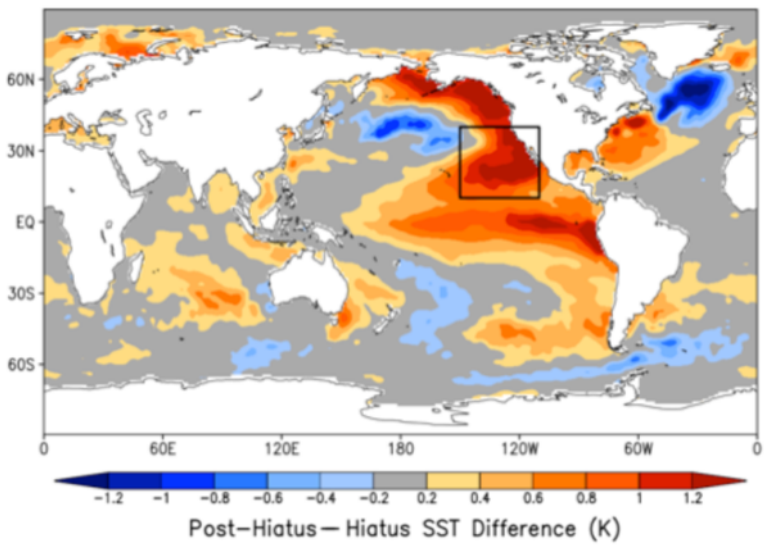
IPCC AR5

Earth's global mean radiation budget. TOA and surface fluxes by CERES & Libera are invaluable for understanding current mean ERB, its variability, and to provide constraints to model predictions.

Libera Science Objective 1



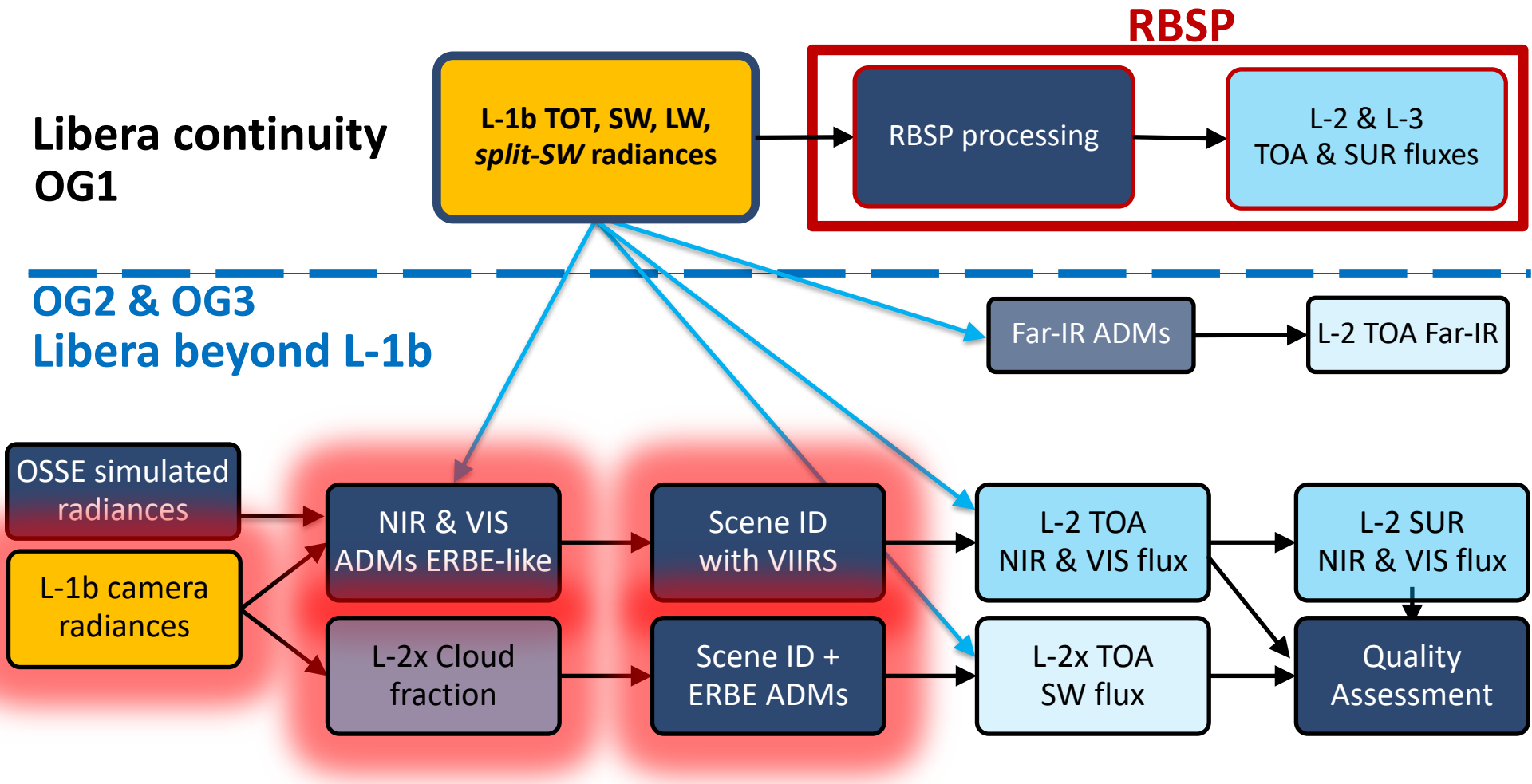
Loeb et al., 2018



Loeb et al., 2020

- What will the *unprecedented* >1.5°C future bring?
- Observational constraint on effect of time-evolving temperature patterns on ERB and feedbacks.
- Team proposes various process studies on different spatio-temporal scales, e.g. focus on poles, tropics, energy transports …
- Better understanding of SW deposition via near-IR & VIS analysis (SO3)

Libera Science & Data Plan



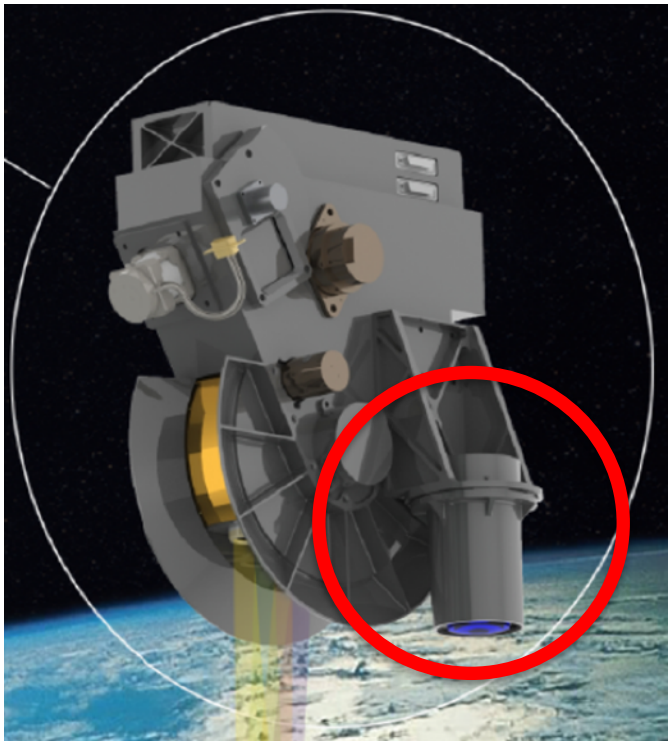
Libera Science Objective 2

OG2: Development of a self-contained, innovative & affordable observing system

Demonstrate feasibility of separating Libera from complex imagers

Science objective 2:

- Explore utility of scene identification from a small and cost-effective camera.
- Develop angular distribution models (ADM) to facilitate shortwave near-IR and visible radiance-to-flux conversion.



Monochromatic (865 nm) wide field of view (WFOV, 140º) camera provides images at 1 km pixel resolution.

S. Schmidt, J. Gristey, D. Feldmann

Libera Science Objective 2

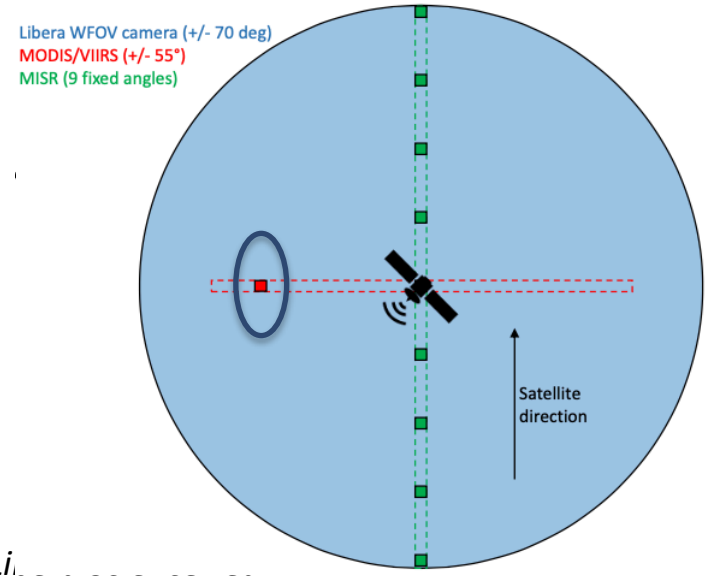
ADMs for VIS and NIR do not exist.

$\frac{\pi L}{F}$ = **ADM for a certain scene type and viewing geometry**

- Traditional ADM development takes years of measurements (RAP).
- Camera angular information accelerates ADM development.
- Single wavelength camera acts as a proxy for the split channels

Measured Radiance L

Estimated Flux F

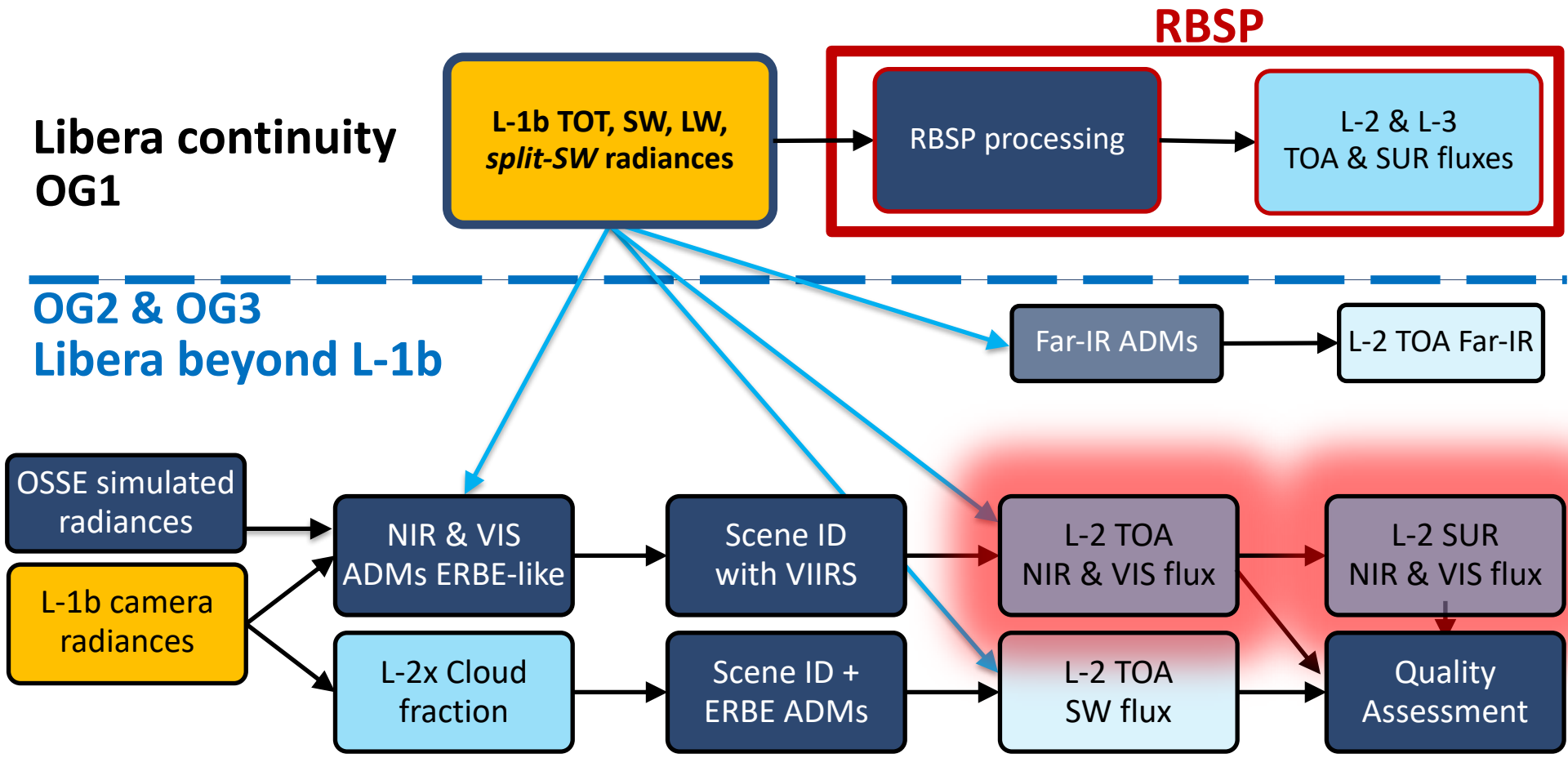


Scene ID Experiment

- Cloud fraction retrieval at 1 km to determine ERBE-like scene within Libera footprint.
- *Adaptative thresholding* over select surface types. (Sun et al, 2016).

Scene	Cloud coverage, percent
Clear over ocean	0 to 5
Clear over land	↓
Clear over snow	↓
Clear over desert	↓
Clear over land-ocean mix	↓
Partly cloudy over ocean	5 to 50
Partly cloudy over land or desert	5 to 50
Partly cloudy over land-ocean mix	5 to 50
Mostly cloudy over ocean	50 to 95
Mostly cloudy over land or desert	50 to 95
Mostly cloudy over land-ocean mix	50 to 95
Overcast	95 to 100

Libera Science & Data Plan

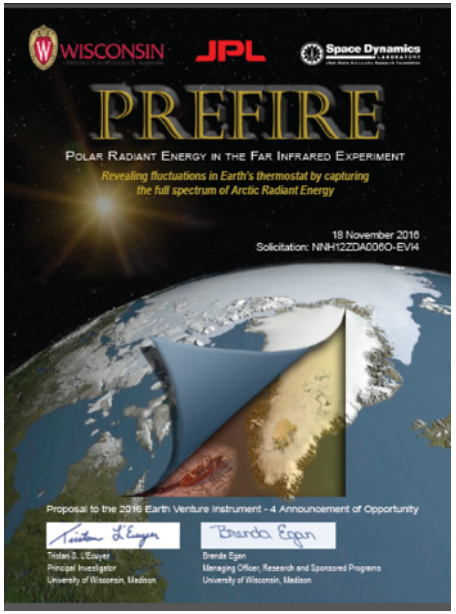


Libera Science Objective 3

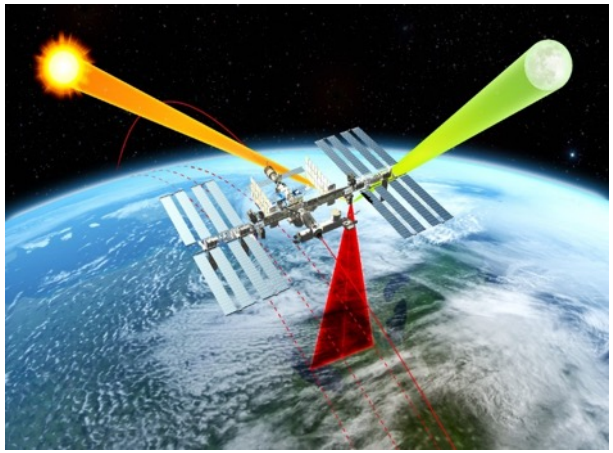
Motivation: The future is spectral

- Spectral signatures of the TOA fluxes reveal insights on processes that shape the ERB and its changes.
- Spectral ERB measurements are on the way:

Spectral OLR - 2022



CLARREO-PF on ISS 2022: spectrally resolved solar



X-element linear array of absolute radiometers to enhance spatial & spectral resolution

O. Coddington

Libera-FO?

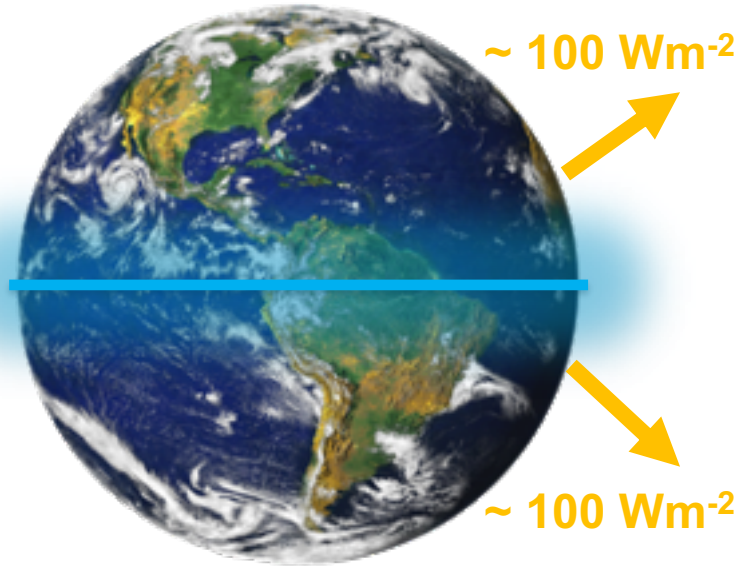
Libera Science Objective 3

OG3: Provide new and enhanced capabilities that support extending ERB science goals.

Science objective 3:

Revolutionize understanding of spatiotemporal variations in SW, VIS and NIR fluxes.

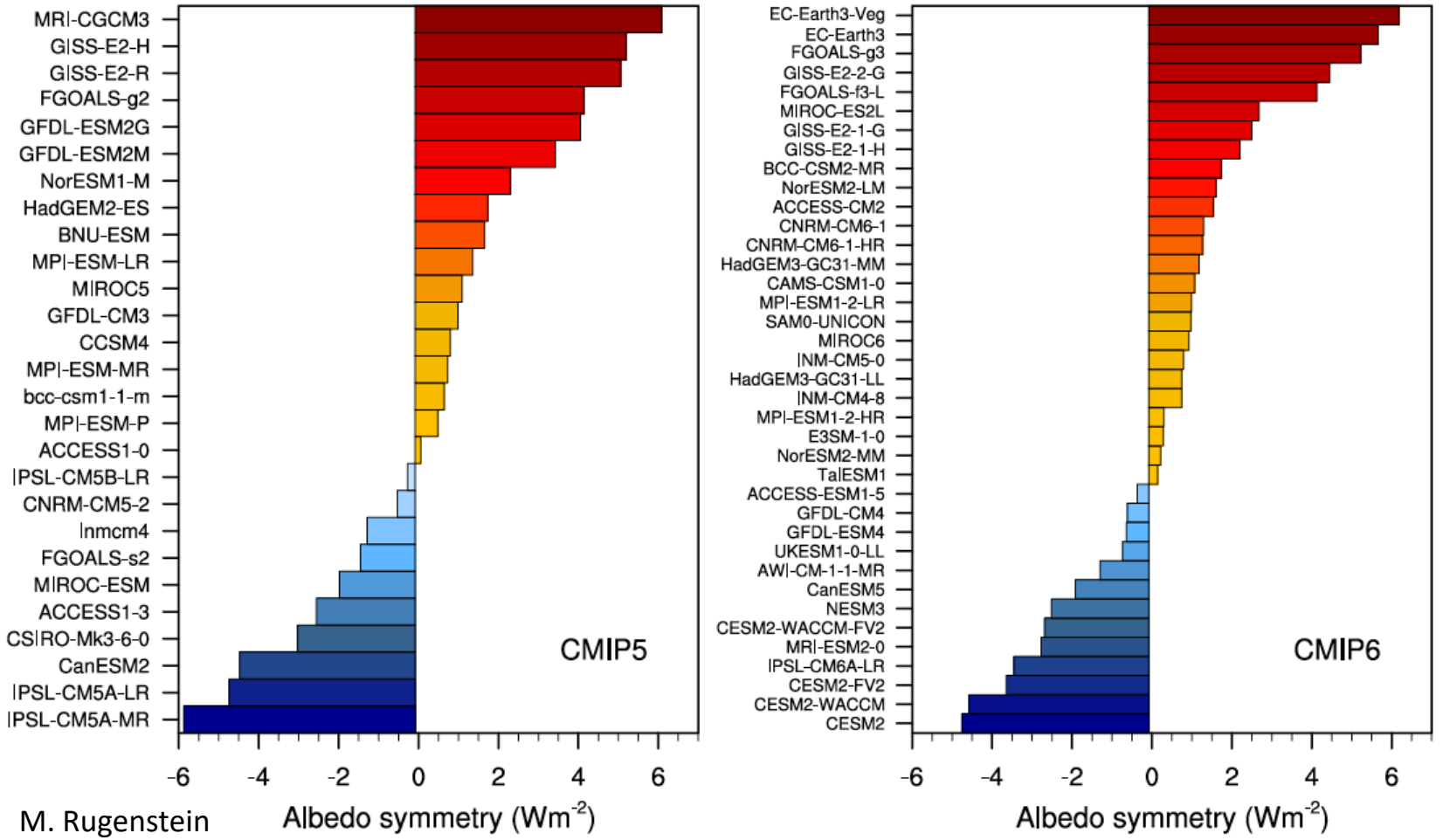
- Employ Split-Shortwave channel to quantify SW energy disposition (split at 700 nm)
- NIR and VIS fluxes at TOA and surface (L2 SSF; **RBSP collaboration anticipated**)
- Characterize NIR & VIS signatures of processes that control the absorption of solar radiation, SW climate feedbacks, and the **hemispheric symmetry of planetary albedo**.



SW reflection may be symmetrical, but spectral "fingerprint" is not!

Hemispheric albedo (a)symmetry

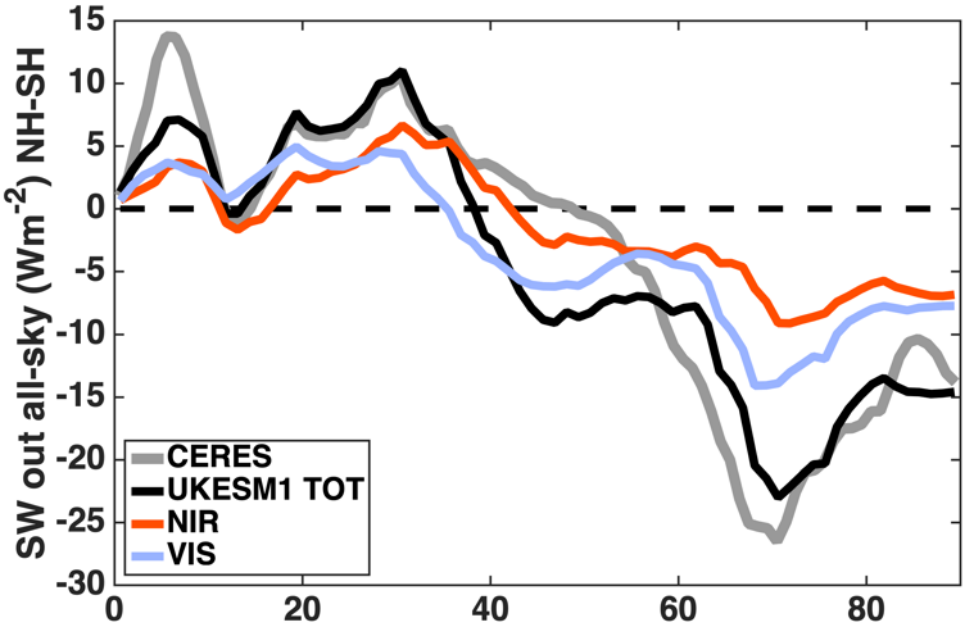
Northern minus Southern hemisphere TOA SW flux in CMIP5 and CMIP6

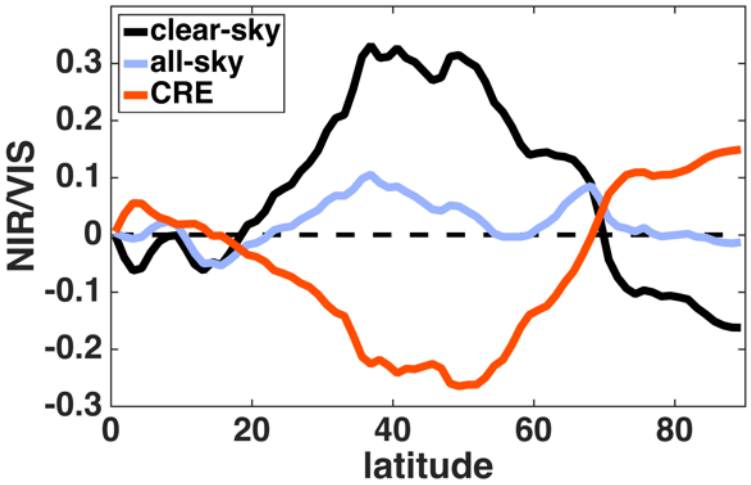


M. Rugenstein

NH-SH differences per latitude in UKESM1

- NH is mostly brighter 0-40 degree, but darker poleward (ITCZ + land vs. extensive cloudiness + seasonal sea ice)
- Model agrees with CERES (?)
- NIR & VIS show similar pattern as total SW (?)



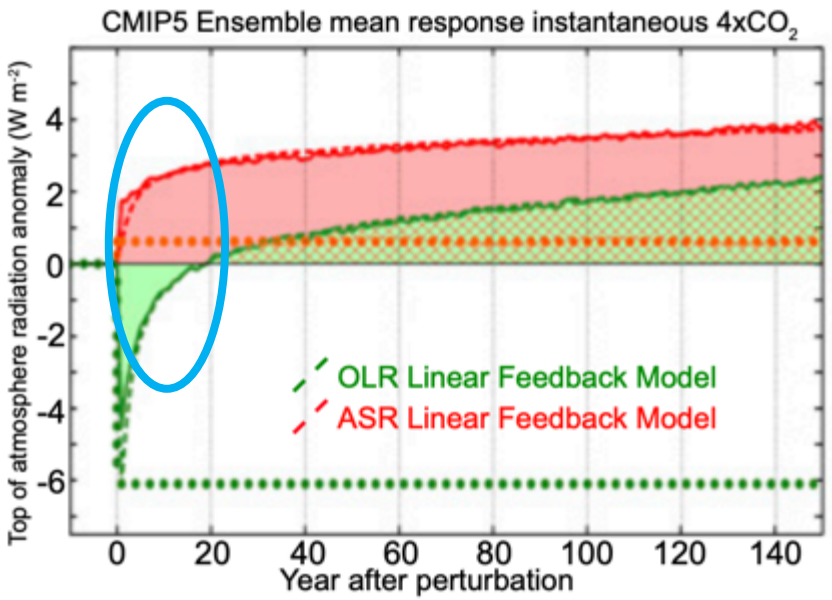


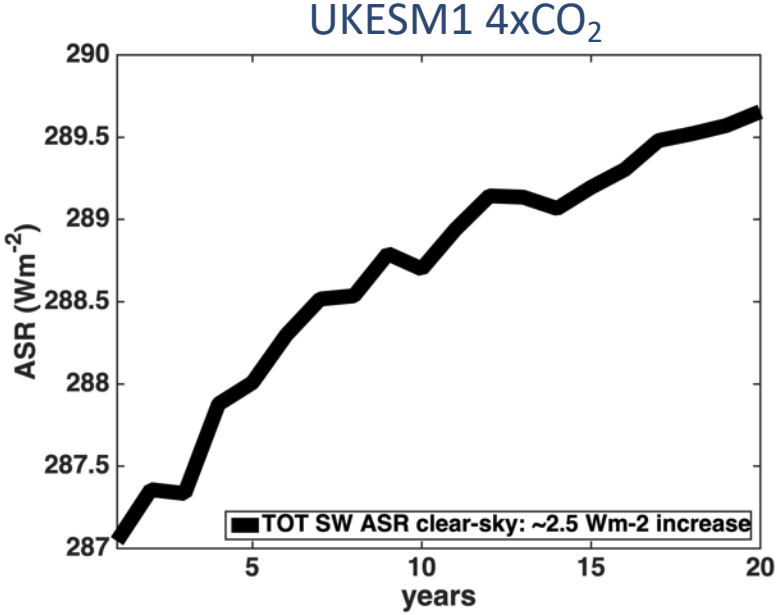
- Positive values: NIR/VIS ratio larger on NH than SH; especially true under clear-sky between 20-70 deg.
- Clouds balance the hemispheres in total SW and also the NIR/VIS ratio.

Data: A. Bodas-Salcedo

UKESM1 4xCO2 time evolutions

Climate model simulations under different future scenarios suggest global warming on decadal to centennial time scales is largely sustained by shortwave absorption (positive climate feedbacks; only clear-sky).

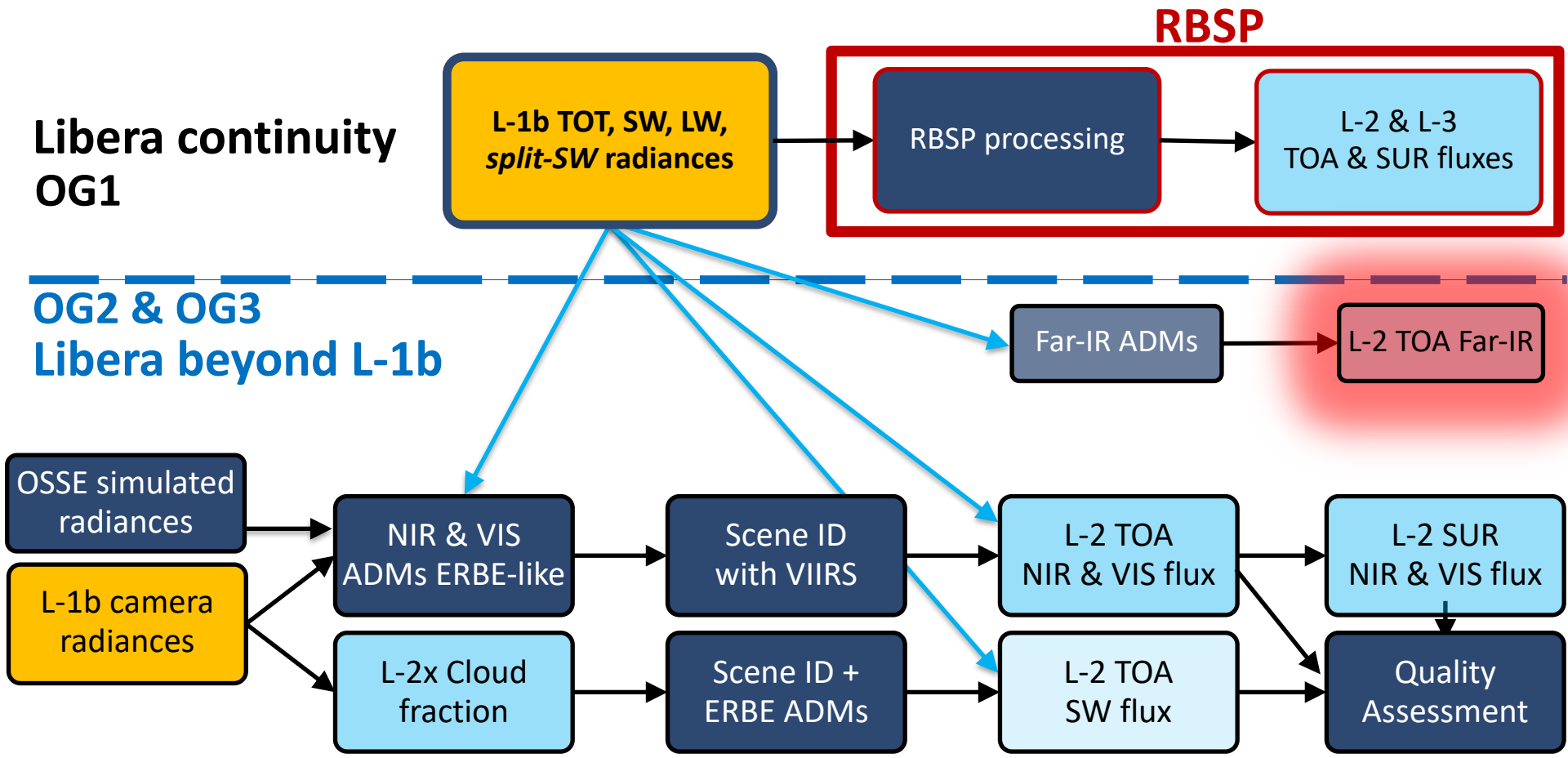




(Donohoe et al., 2014).

- Both analysis show same 2.5 Wm^{-2} increase in clear-sky ASR after about 20 years.
- 60% of this increase occurs in near-IR, 24% in the VIS, the rest in the UV

Libera Science & Data Plan



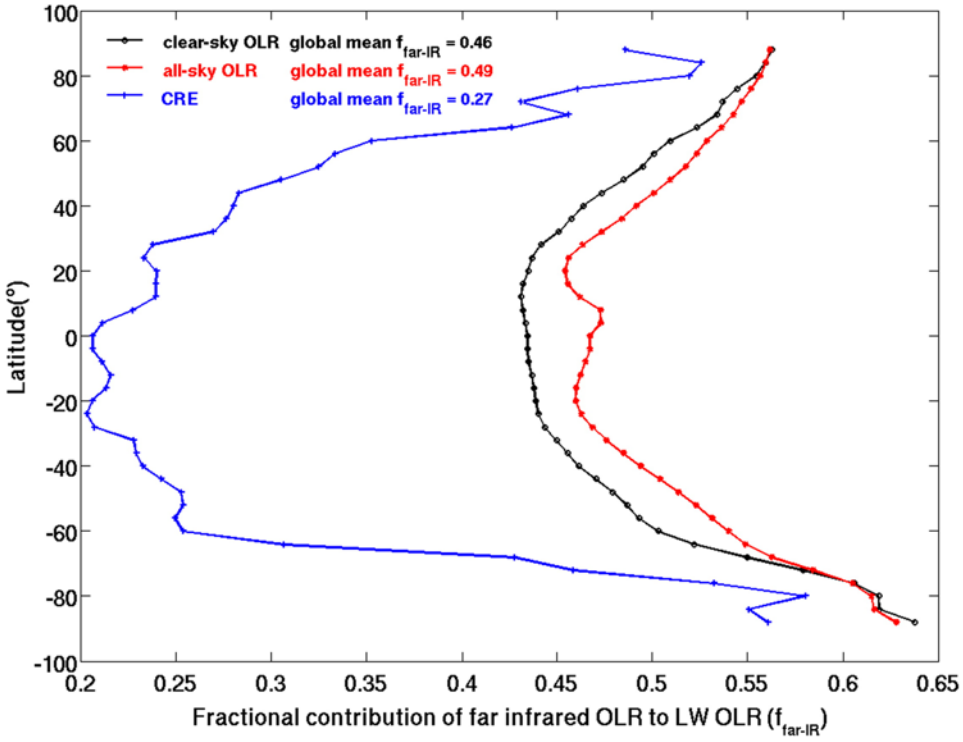
Libera Science Objective 3B

X. Huang

SO3B: Derive Far-IR flux and improve understanding of upper tropospheric water vapor and cloud contributions to ERB variability.

- Like FM6, Libera measures LW (5-50 µm), SW (0.3-5 µm) and TOT (0.3->100 µm) radiances.
- TOT – (SW+LW) = far-IR (50-100µm)
- This complements the proposed measurements of the PREFIRE and FORUM (ESA) missions.
- To-date, specific measurement of far-IR does not exist, but is crucial for better understanding ERB variability.

Far-IR contribution to OLR is ~ 50%



Huang et al., 2014

Libera Science & Data Plan

Products & tasks	Specifics	Responsible	Team lead
L-1b radiances	TOT, LW, SW to RBSP	LASP	Peter Pilewskie
L-1b camera radiances	865 nm (15 nm), WFOV	LASP	Sebastian Schmidt
OSSE simulated radiances	Multi-spectral, multi-angle	LBL	Daniel Feldman
ADMs NIR & VIS	ERBE-like	NOAA/CIRES	Jake Gristey
Cloud fraction & Scene ID	L-2x, 1km, instantaneous ERBE-like	LASP	Sebastian Schmidt
TOA fluxes NIR & VIS	L-2x, SSF, ERBE-like	LASP/JPL	Maria Hakuba
SUR fluxes NIR & VIS	L-2 & L-3, SSF	UA	Xiquan Dong
Far-IR fluxes	TOT-(SW+LW), L-2 TOA	UM	Xianglei Huang
Quality assessments	NIR & VIS fluxes; TOA & SUR	JPL	Maria Hakuba
SO1 & SO3 Science	Beyond data production	All	All

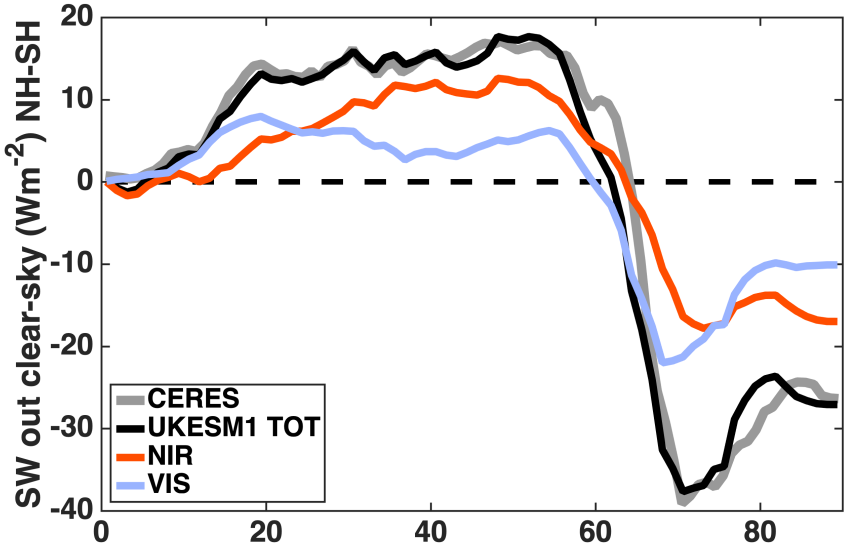
PI: Peter Pilewskie PS: Graeme Stephens DPI: Maria Hakuba

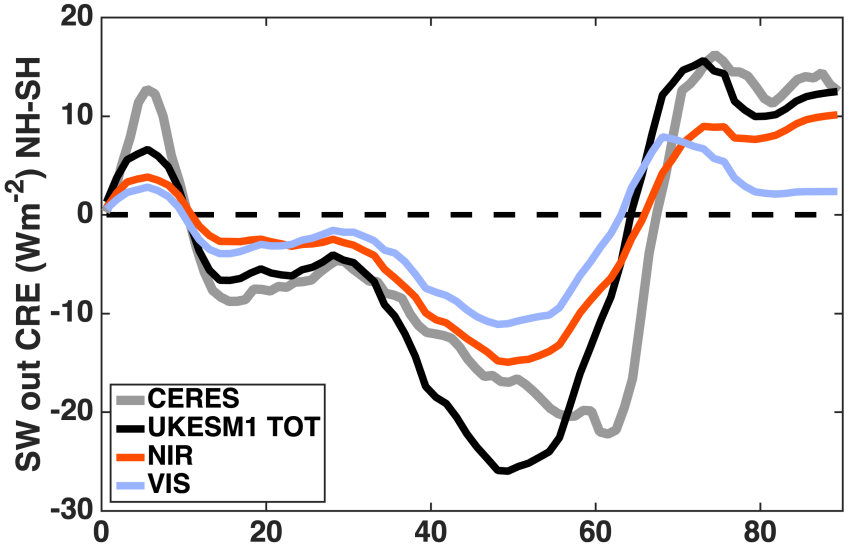
Libera Science beyond L-1b

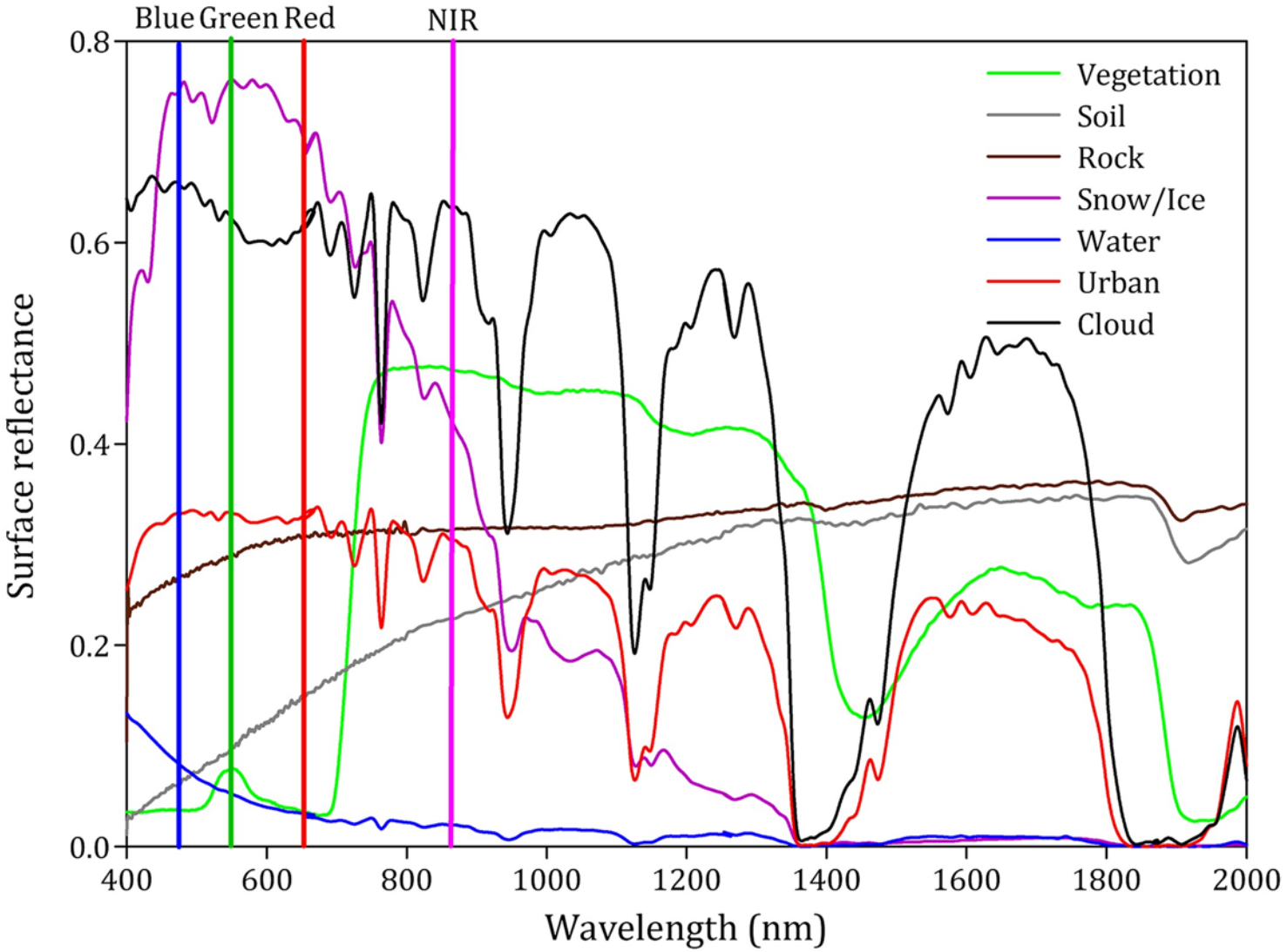
- Advance process understanding of ERB decadal variability
  - On various spatial and temporal scales.
- Additional split-SW channel serves to advance ERB science
  - NIR & VIS variability is associated with processes that control the absorption of solar radiation and the hemispheric symmetry of planetary albedo.
- Far-IR radiances are the residual of the TOT, LW, and SW channels
  - Provide valuable information on the upper-tropospheric contribution to ERB variability especially near the poles.
- Demonstrate future separation from complex imagers
  - Testbed is a WFOV camera employed to identify clouds and to aid in ADM development for NIR & VIS radiance-to-flux conversion.
- **We look forward to a close collaboration with the CERES team!**

Libera Science Team

Name	Role
Peter Pilewskie, *CU LASP*	Principal Investigator
Maria Hakuba	Deputy PI
Graeme Stephens	Project Scientist
Odele Coddington	Surface Radiation Budget
Bill Collins	Climate Modeling
Sandie Collins	Instrument LW Calibration
Xiquan Dong	Surface & TOA Fluxes
Daniel Feldman	Climate OSSEs
Jake Gristey	ADMs
Dave Harber	Instrument Scientist
Xianglei Huang	Longwave Radiation Budget
Thomas Kampe	Camera Science
Bruce Kindel	Clouds & Aerosols
John Lehman	Detector Metrology
Jim Leitch	JPSS Interface
Steve Massie	Clouds & Aerosols
Sebastian Schmidt	Camera Science Lead
Tom Vonderhaar	ERB Continuity
Zhien Wang	Aerosols
Chris Yung	Detector Metrology
Richard Allan	Radiative Energy Balance
Doris Folini	GCM/Earth System Models
Jacqueline Russell	TOA Radiation Budget
Martin Wild	Global Energy Budget
Alejandro Bodas-Salcedo	Climate Modeling


SW out clear-sky (Wm-2) NH-SH
20
10
0
-10
-20
-30
-40
0
20
40
60
80
CERES
UKESM1 TOT
NIR
VIS


SW out CRE (Wm-2) NH-SH
20
10
0
-10
-20
-30
0
20
40
60
80
CERES
UKESM1 TOT
NIR
VIS


Blue Green Red
NIR
Vegetation
Soil
Rock
Snow/Ice
Water
Urban
Cloud
Surface reflectance
0.0
0.2
0.4
0.6
0.8
400
600
800
1000
1200
1400
1600
1800
2000
Wavelength (nm)